PB-250 543

A SECOND EVALUATION OF THE QUESTOR EMISSION CONTROL SYSTEM

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Environmental Protection Agency
Ann Arbor, Michigan

November 1972

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079020

APTD-1384.

73-9

PB 250 543

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U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

BIBLIOGRAPHIC DATA SHEET	1. Report No. APTD-1384	2.	3. Recipient's Accession No.
4. Title and Subtitle A Second Evaluation of the Questor Emission Control System			5. Report Date November, 1972 6.
7. Author(s) Thomas C. Austin			8. Performing Organization Rept. No.
9. Performing Organization Name and Address Test and Evaluation Branch Division of Emission Control Technology Environmental Protection Agency Ann Arbor MI 48105			10. Project/Task/Work Unit No. 11. Contract/Grant No.
12. Sponsoring Organization Name and Address Test and Evaluation Branch Division of Emission Control Technology Environmental Protection Agency Ann Arbor, MI 48105			13. Type of Report & Period Covered 14.

15. Supplementary Notes

16. Abstracts

The Questor emission control system can acieve the 1976 Federal emission levels at low mileage. Durability is yet to be demonstrated. The Questor system causes a considerable loss in fuel economy in stop and go driving. There appears to be, however, potential for reducing this penalty by modulating air injection as a function of engine load which would allow leaner calibration. Particulate emission levels from the Questor system appear to be lower than those from conventional systems using lead fuels. Future testing will be required to verify the preliminary results.

17. Key Words and Document Analysis. 17a. Descriptors

Air pollution
Performance tests
Automotiv e emissions

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

PRICES SUBJECT TO CHANGE

18. Availability Statement	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 12
1<	20. Security Class (This Page) UNCLASSIFIED	22. Price $3.50

Background

EPA recently performed a short evaluation of a vehicle prepared by Questor Automotive Products of Toledo, Ohio. The vehicle equipped with the Questor "Reverter" emission control system had been available only long enough for one 1975 Federal Test Procedure to be run. Because of the impressive emission levels recorded during the first EPA test (below 1976 requirements) a decision was made to perform a more extensive evaluation at a later date.

Approximately 4,000 miles had been accumulated on the Questor vehicle since the first test. Total system mileage was approximately 8,000 at the beginning of this test series. Questor representatives claimed that all of the mileage had been accumulated using highly leaded fuels. A lead determination, performed by EPA, on a sample of fuel from the vehicle's tank indicated a lead content of 2.5 grams per gallon.

Vehicle Tested

The Questor "Reverter" emission control system was installed on a 1971 Pontiac Catalina equipped with a 400 CID V-8 engine, automatic transmission and air conditioning. The heart of the system is a pair of non-noble reduction catalysts sandwiched between partial thermal reactors. Carburetor calibration and exhaust port air injection rates are set such that a reducing atmosphere is still present after the exhaust gas passes through the first partial thermal reactor stage. After the exhaust gas passes through the NO_x catalyst, additional air is added to complete combustion of the HC and CO remaining. Exhaust gas recirculation (EGR) is not used.

One "reverter" is used on each bank of a V-8 engine. Figure 1 is an illustration of a reverter attached to a cylinder head. "Limited oxidation" and "final oxidation" takes place in the partial thermal reactors. The "reduction zone" houses the expanded metal NO_x catalyst. Figure 2 shows a cut-away reverter system installed on a cylinder head. As can be seen from the picture, the construction is double walled to reduce heat loss.

The vehicle's exhaust system is constructed of double walled pipe. Air pump discharge is routed to the rear of the vehicle and pumped into the annular cavity surrounding the inner exhaust pipe. The air is then heated by the hot inner pipe as it is pumped toward the front of the vehicle where it is removed from the annular cavity and injected into the partial thermal reactors at 800° F.

Incorporated in the Questor vehicle is a sub-system to improve fuel economy and reduce system temperatures during high load operation. This system, designated "Normal Operating Temperature Control (N.O.T.C.)" senses both load and time. When the vehicle is exposed to a high enough load for a long enough period of time a portion of the air pump discharge is diverted to the intake manifold, causing enleanment of the mixture. The system is activated when two separate chambers are pressurized by a portion of the air pump discharge. The time required to pressurize the chambers depends on the air pump speed (a function of vehicle speed) and the exhaust backpressure (a function of vehicle load). Normally at loads below those required for a 50 mph cruise the system will never activate because the air pump discharge cannot overcome the built-in leakage in the chambers. Above 50 mph the system will only activate if the driver maintains a steady throttle position and does not use his brakes. Brake application causes one of the volumes to dump immediately.

As adjusted on this vehicle the N.O.T.C. system would only be activated during expressway or highway operation in light traffic. Activation causes a considerable loss in NO_x control but good HC and CO control is maintained. Our previous testing of the Questor vehicle indicated that fuel economy of better than 15 miles per gallon could be achieved at 60 mph cruise with the system activated. Properly calibrated the system would not be activated in heavy traffic situations or stop and go driving. As installed on the vehicle tested, the N.O.T.C. system was fully adjustable. A production version would use fixed orifices rather than adjustable valves. The system was never activated during the LA-4 driving cycle of the Federal Test Procedure.

Test Program

The Questor vehicle was tested using the 1975 Federal Test Procedure with two different vehicle weights simulated. Two tests were run at a 5,000 pound test weight, the "correct" test weight for the full size Pontiac and two tests were run at a reduced weight of 3,000 pounds simulating a compact vehicle. A description of the Federal Test Procedures is enclosed (Attachment I).

In addition to the gaseous emission tests, the vehicle was also tested for particulate emissions. The particulate testing was done by Dow Chemical of Midland, Michigan through an existing EPA contract. The Dow procedure simulates an air quench of the vehicle's exhaust gas by routing the exhaust into a 15-7/8 inch diameter tube where it is diluted to a 500 cfm flow. Twenty-seven feet downstream of the tailpipe samples are pulled from the diluted exhaust through fiberglass filters, millepore filters and an Anderson impactor. Only the particulates still in suspension are captured. While the Dow procedure is not necessarily going to end up as a Federal Procedure, it does allow us to compare particulate emission levels from different vehicles using a common procedure.

Test Results

Results are summarized in Tables I and II. Table I lists gaseous emission test results using the 1975 Federal Test Procedure for test weights of both 5,000 and 3,000 pounds. Emissions were under the 1976 levels during each test. Hydrocarbon control was very good. During the only test above .03 grams per mile HC (16-0023) the vehicle did not restart well after the ten minute soak. NO_x control was quite good. A 40% reduction in test weight from 5,000 pounds to 3,000 pounds caused a 36% reduction in NO_x levels. CO levels were much lower than normally expected from vehicles using thermal reactors to control CO.

Fuel economy at 5,000 pounds test weight averaged 6.93 miles per gallon. This represents a 20% penalty compared to the average of all 1973 certification prototypes tested by EPA during the spring and summer of 1972.

(Corrections were made for the slight difference in test procedure.) The fuel economy improvement measured when the test weight was lowered to 3,000 pounds was not very large because the carburetion, engine size, and driveline were poorly matched for a lighter weight application.

Results of the particulate testing are listed in Table II. At 60 mph steady state the particulate levels were comparable to a vehicle using 0.5 grams per gallon lead fuel. An EPA lead determination run on the gasoline used during the Questor testing indicated a lead level of 2.87 grams per gallon. A conventional (1970 production Chevrolet) run with 3.0 gram fuel emitted particulate levels over four times greater than the Questor vehicle. More data points will be required to lend significance to the results.

Conclusions

1. The Questor emission control system can achieve the 1976 Federal emission levels at low mileage. Durability is yet to be demonstrated.

2. The Questor system causes a considerable (≈25%) loss in fuel economy in stop and go driving. There appears to be, however, potential for reducing this penalty by modulating air injection as a function of engine load which would allow leaner calibration.

3. Particulate emission levels from the Questor system appear to be lower than those from conventional systems using leaded fuels. Future testing will be required to verify the preliminary results.

TABLE I

Questor Emission Control System

1975 Federal Test Procedure

(emission data in grams per mile)

- 5000# Test Weight -

Test Number	HC	CO	NO_x	mpg
16-0023	.23	2.55	.34	6.89
16-0033	.01	1.98	.31	6.96
Average	.12	2.27	.33	6.93

- 3000# Test Weight -

Test Number	HC	CO	NO_x	mpg
16-0029	.03	1.66	.22	7.73
16-0034	.02	2.55	.20	7.70
Average	.03	2.11	.21	7.72

TABLE II

Particulate Emissions

(all data in grams per mile)

Vehicle	Fuel	Hot Start 72 FTP	60 mph steady state
Questor 101	2.87 gpg Pb	.15	.025
1971 Chevrolet	.5 gpg Pb	-	.021
1970 Chevrolet	3.0 gpg Pb	-	.110

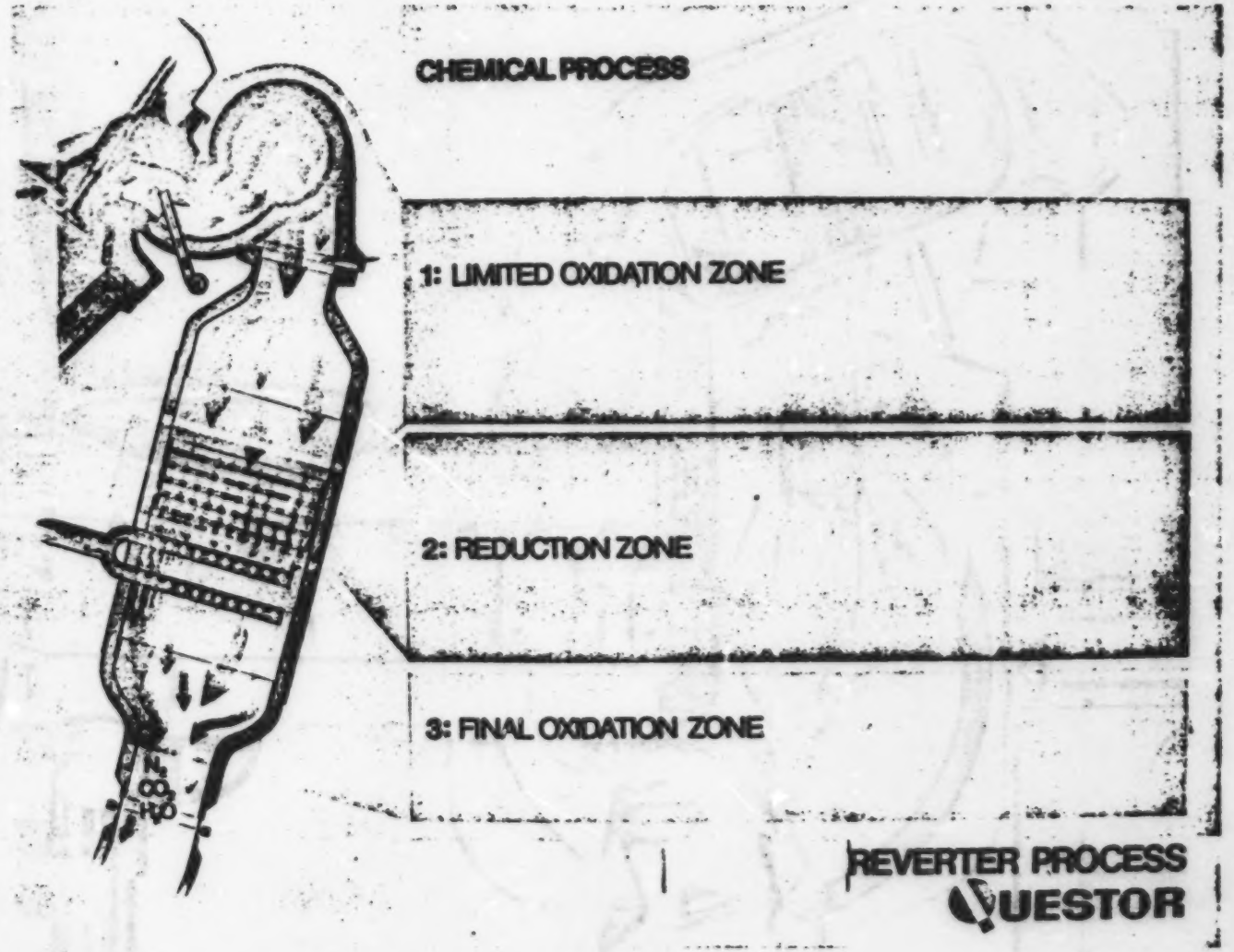
CHEMICAL PROCESS
1: LIMITED OXIDATION ZONE
2: REDUCTION ZONE
3: FINAL OXIDATION ZONE
REVERTER PROCESS
QUESTOR

FIGURE 1.

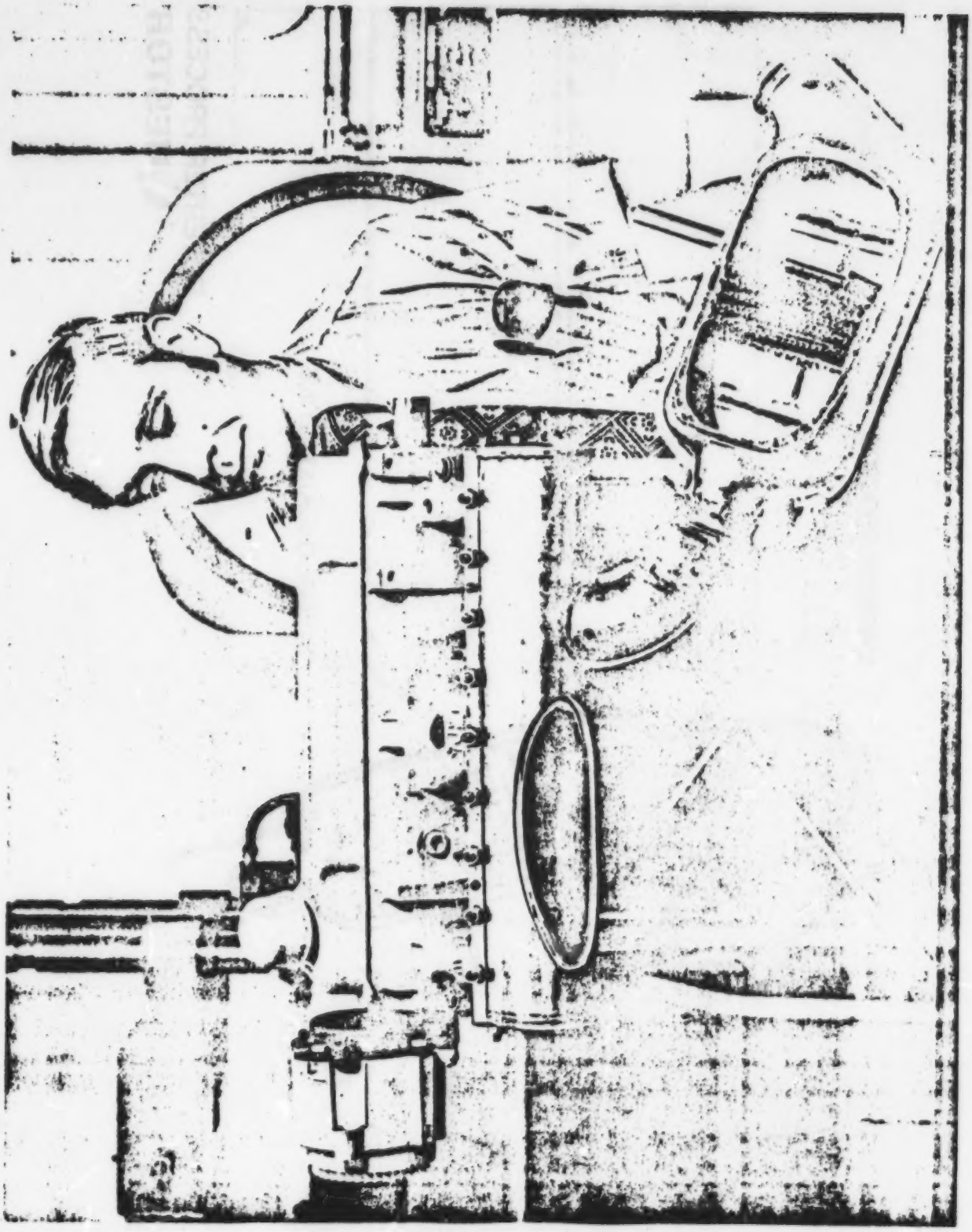

FIGURE 2.

FEDERAL EMISSION TESTING PROCEDURES FOR LIGHT DUTY VEHICLES

The Federal procedures for emission testing of light duty vehicles involves operating the vehicle on a chassis dynamometer to simulate a 7.5 mile (1972 procedure) or 11.1 mile (1975 procedure) drive through an urban area. The cycle is primarily made up of stop and go driving and includes some operation at speeds up to 57 mph. The average vehicle speed is approximately 20 mph. Both the 1972 and 1975 procedures capture the emissions generated during a "cold start" (12-hour soak @ 68°F to 86°F before start-up). The 1975 procedure also includes a "hot start" after a ten minute shut-down following the first 7.5 miles of driving.

Vehicle exhaust is drawn through a constant volume sampler (CVS) during the test. The CVS dilutes the vehicle's exhaust to a known constant volume with make up air. A continuous sample of the diluted exhaust is pumped into sample bags during the test.

Analysis of the diluted exhaust collected in the sample bags is used to determine the mass of vehicle emissions per mile of operation (grams per mile). A flame ionization detector (FID) is used to measure unburned hydrocarbon (HC) concentrations. Non-dispersive infrared (NDIR) analyzers are used to measure carbon monoxide (CO) and carbon dioxide (CO_2). A chemiluminescence (CL) analyzer is used to determine oxides of nitrogen (NOx) levels.

These procedures are used for all motor vehicles designed primarily for transportation of property and rated at 6,000 pounds GVW or less, or designed primarily for transportation of persons and having a capacity of twelve persons or less. Each new light duty vehicle sold in the United States in model years 1973 and 1974 must emit no more than 3.4 gpm HC, 39. gpm CO and 3.0 gpm NOx when using the 1972 procedure. In 1975 the standards will change to .41 gpm HC. 3.4 gpm CO and 3.1 gpm NOx using the 1975 procedure. In 1976 the standards will be .41 gpm HC, 3.4 gpm CO and .4 gpm NOx using the 1975 procedure.